



SERDP PP1151 - ID Plasma Spray

HCAT Program Review
Cocoa Beach, FL
December 2000

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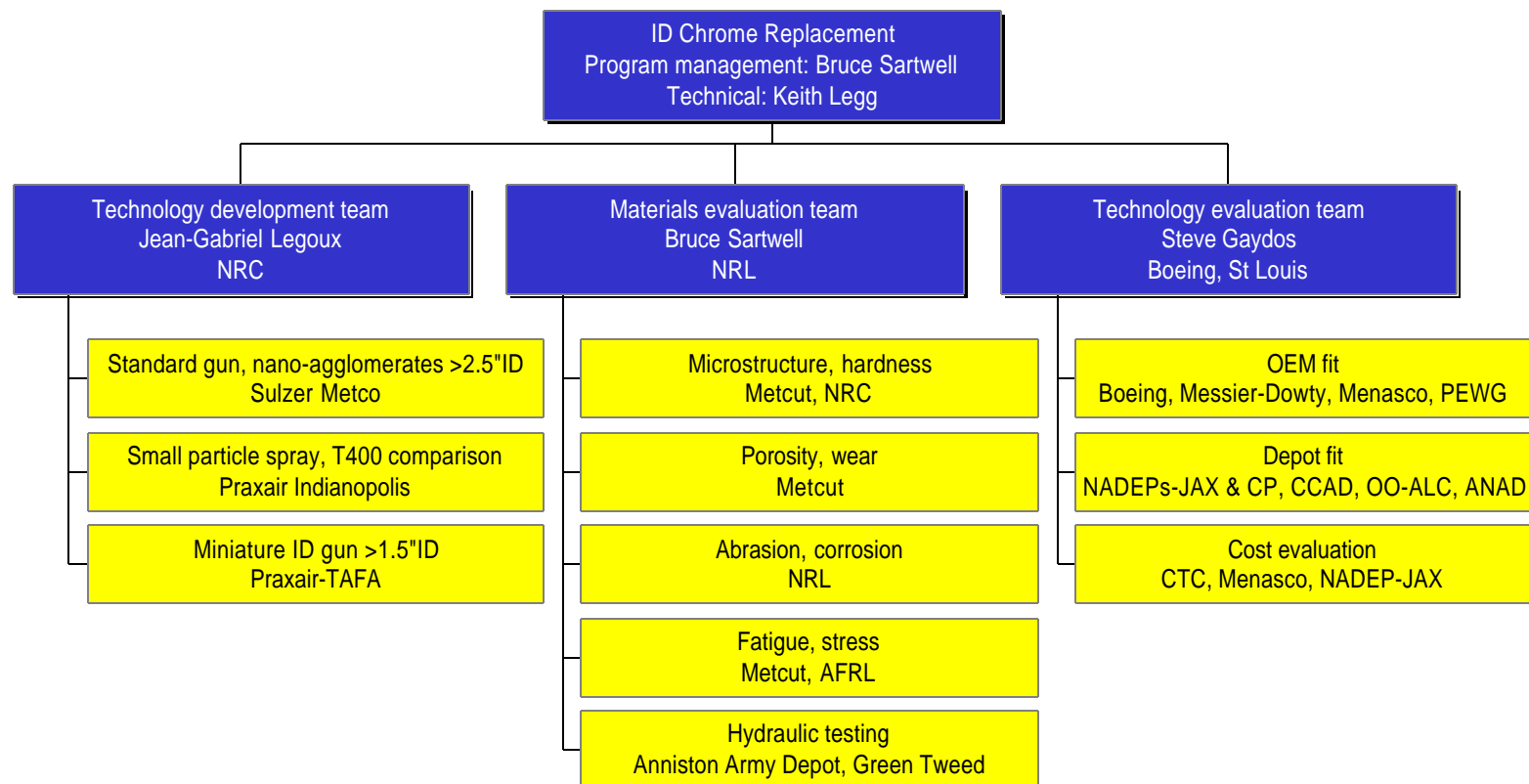
Technical objective

- **To demonstrate proof-of-principle for the plasma spray method:**
 - Improve ability to spray in constricted areas; miniature gun and process modifications
 - Understand limits, improve coating performance and reliability
 - Improve underlying science and technology of plasma spray
 - Improve coating properties by use of small and nano-agglomerate particles
 - Feed results into follow-on dem/val as soon as possible for use in new weapons platforms (e.g. JSF) and maintenance of existing systems




Technical background

- HVOF thermal spray coatings (primarily WC-Co) on ODs have proved superior to electrolytic hard chrome
 - Less wear and fatigue - “lifetime coatings” in some cases
 - Lower life-cycle cost
- Wide variety of wear-resistant materials to meet diverse needs
 - WC-Co meets most needs
 - Tribaloy and stainless steel for lower wear applications
- But HVOF cannot be used in IDs < about 11”
- Use of plasma and arc spray growing for IDs
 - Not yet developed enough for high pressure landing gear hydraulics or for IDs < 3” (e.g. actuators)

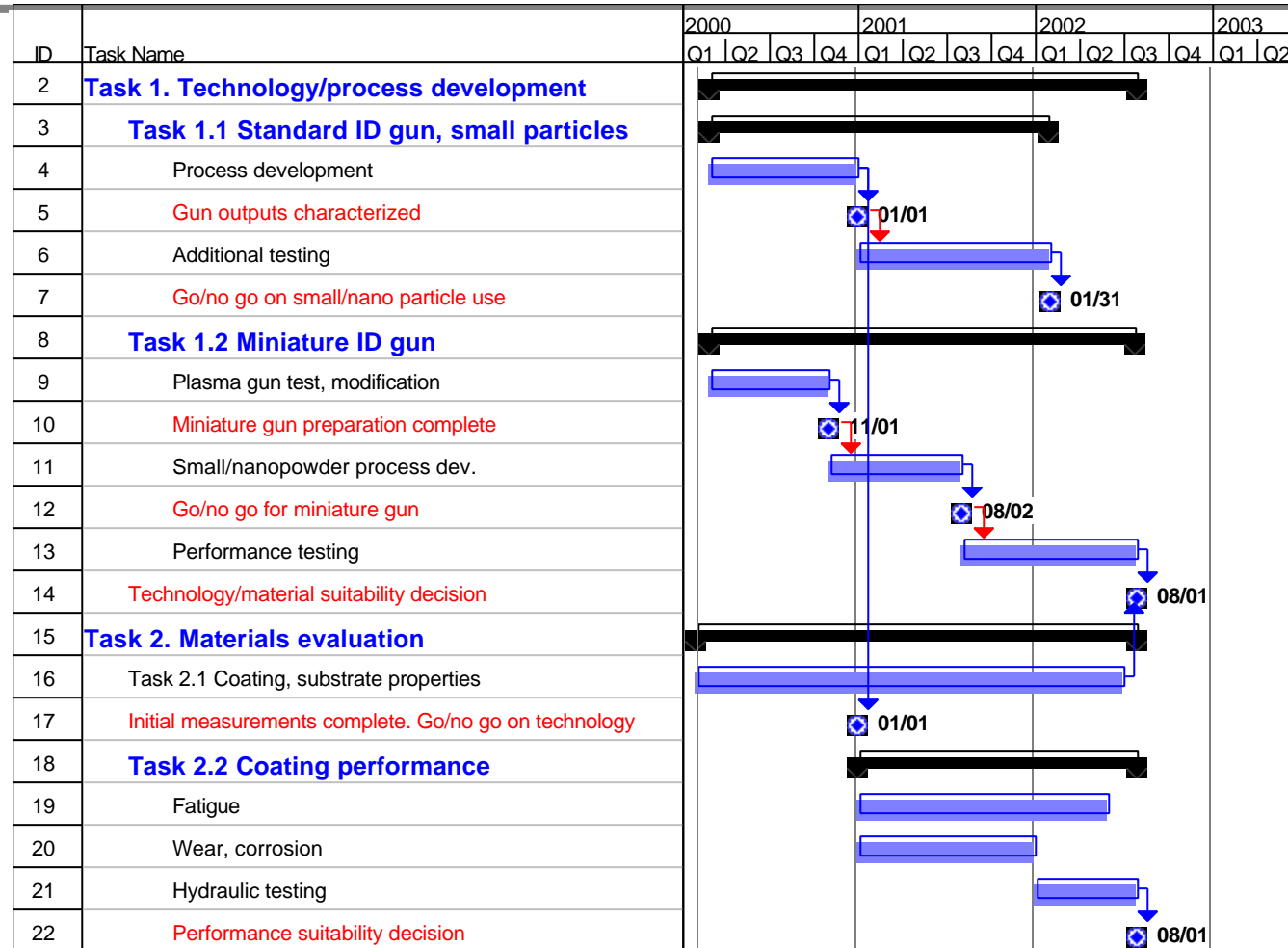
Team



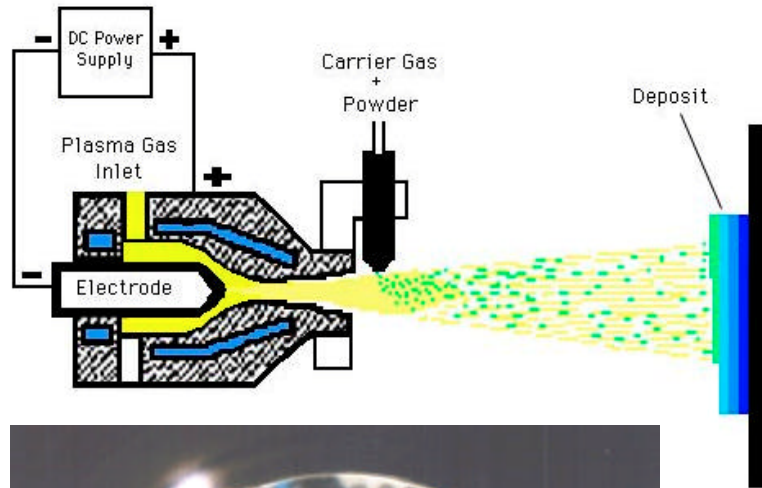
Technical Approach - Summary of Technology Development approach

	Praxair-TAFA	Praxair Indianapolis	Sulzer Metco	NRC
Equipment	 Praxair 2700 miniature 30kW, 1.5" ID		 Sulzer Metco F-100 20 kW 4" ID  Sulzer Metco F-210 12kW, 2.5" ID	All guns Characterize performance – velocity and temperature profiles
Powder	Standard WC-Co Small particles Nano-agglomerates	Tribaloy 400 WC-Co small particles	Standard WC-Co powders Nano-agglomerate WC-Co	All powders Optimize spray conditions Consider other materials
Issues	How small a diameter can we coat? And with what type of powder?	Do small particles provide better quality?	Best conditions for large parts – landing gear outer cylinders Do nanoparticles give better particles? – OSH issues	Characterize coatings and coated tubes Evaluate OSH issues of nanopowders

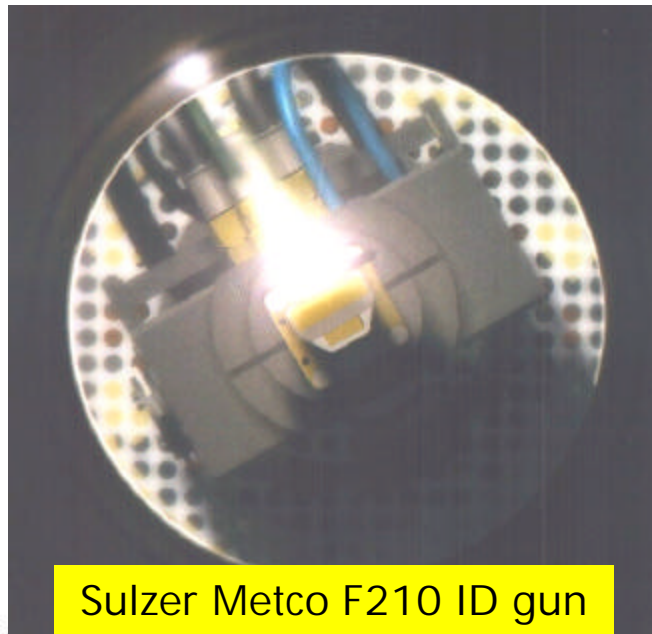
Overall plan - technical



Technical background

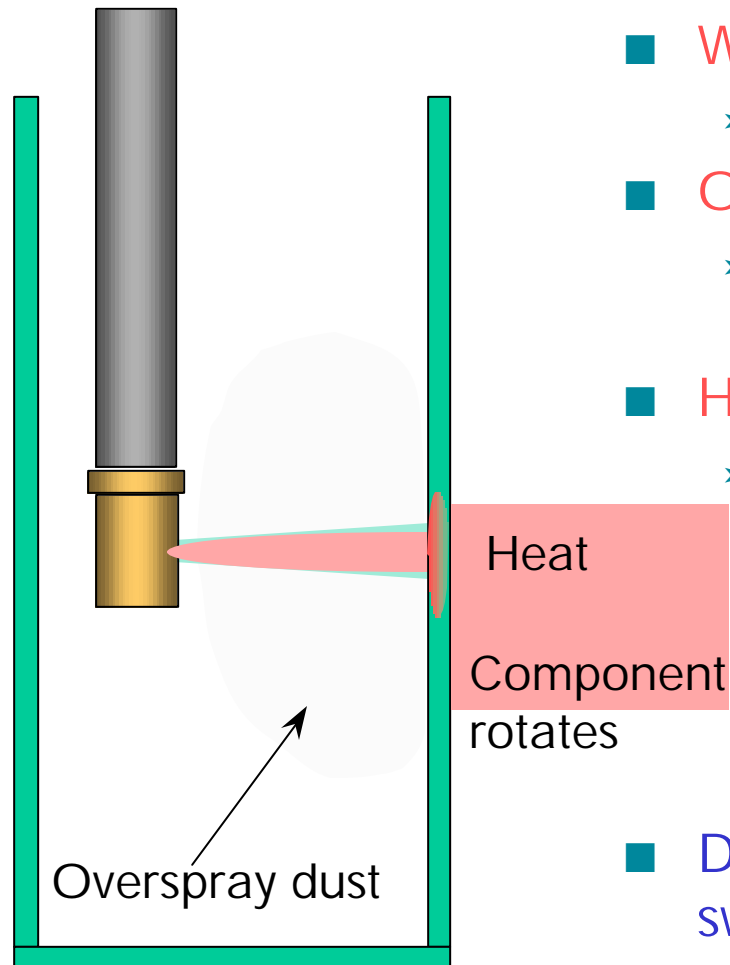


- Powder particles injected into plasma plume accelerate, heat, soften, splat onto surface
- Typical particle size - 50 μ m
- Typical coating thickness - 0.001" - 0.020"
- Hardness - 1,000 - 1,500 HV (EHC is 800 - 1,000 HV)
- Coating rate high - landing gear inner cylinder OD typically takes 20 min



Sulzer Metco F210 ID gun

Technical approach - critical issues



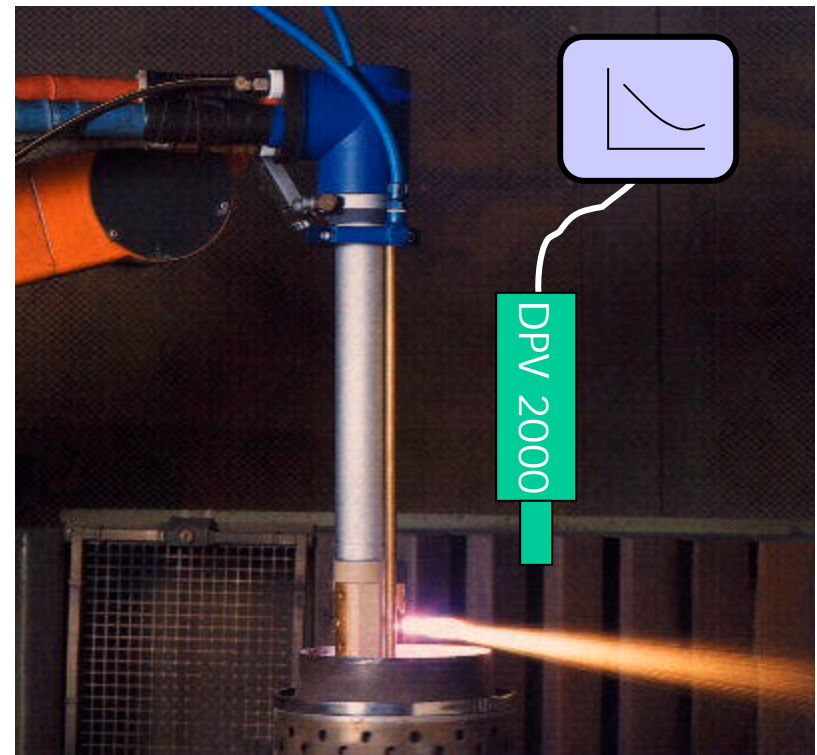
- What is smallest ID we can coat?
 - Smallest gun, standoff, best particles
- Overspray dust incorporation
 - Porosity
 - ❑ additional gas flow to remove particles
- Heat removal
 - Overheat component
 - ❑ additional gas flow to remove heat
 - ❑ minimize plasma power
 - reduces powder overheating
 - allows smaller particles
 - » less porosity, smoother
- Design internal gas flow to cool and sweep out particles

Specimen Holder Simulating ID - NRC, Montreal



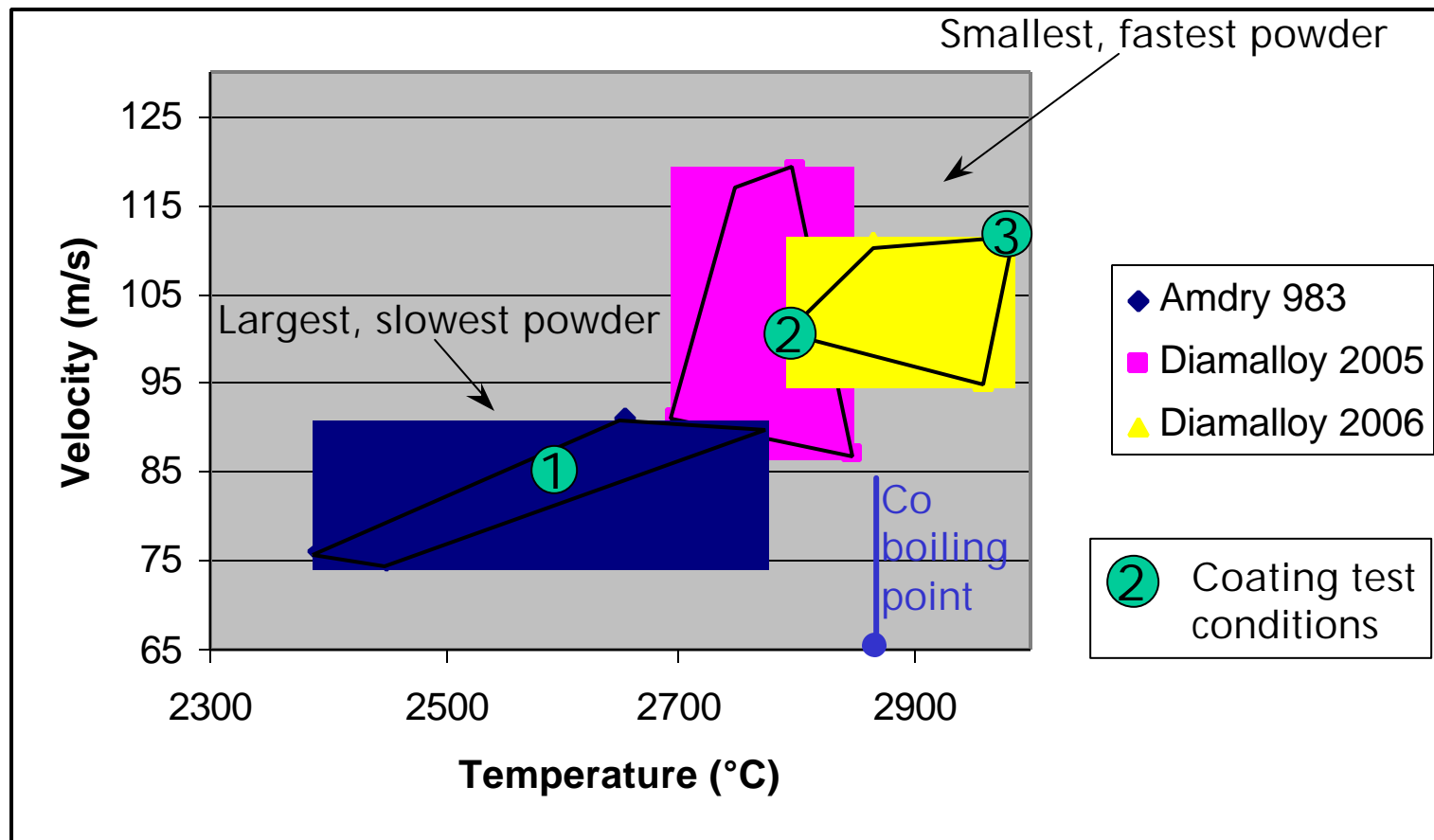
Initial testing - NRC

- Initial aim to feel out the process and limitations of standard spray conditions and powders
- 3 WC-17Co powders sprayed with Sulzer Metco F-100 gun
 - Used for larger IDs ($>4''$)
- DPV 2000 spray monitor
 - Measures particle temperature and velocity along spray jet



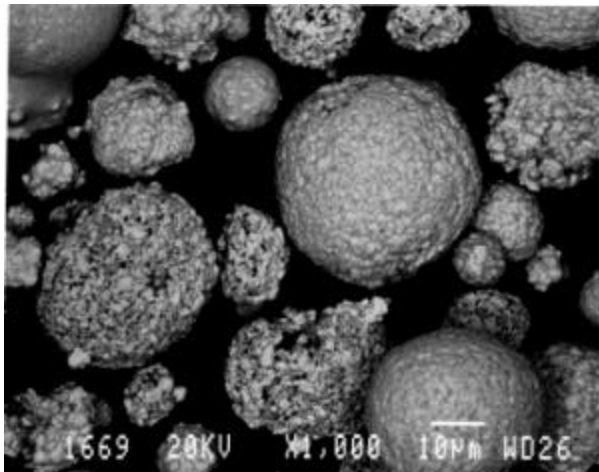
Operating Ranges

SM F-100 gun with 3 WC-Co powders

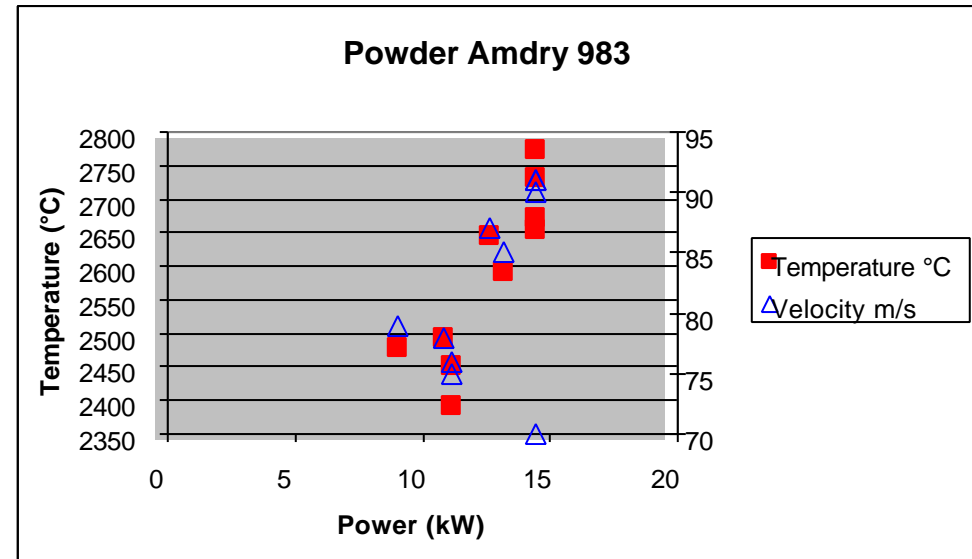
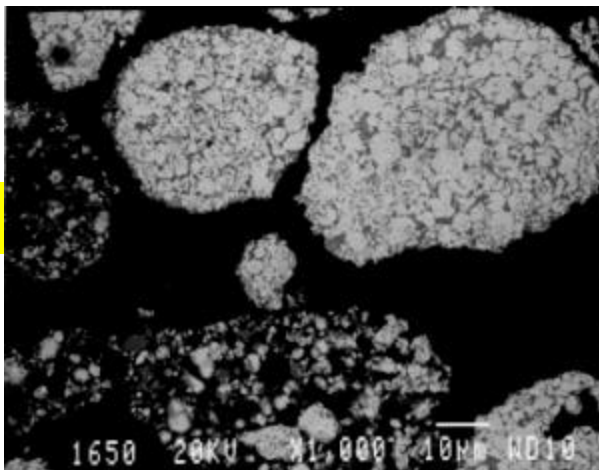


Spray analysis - Amdry 983 powder

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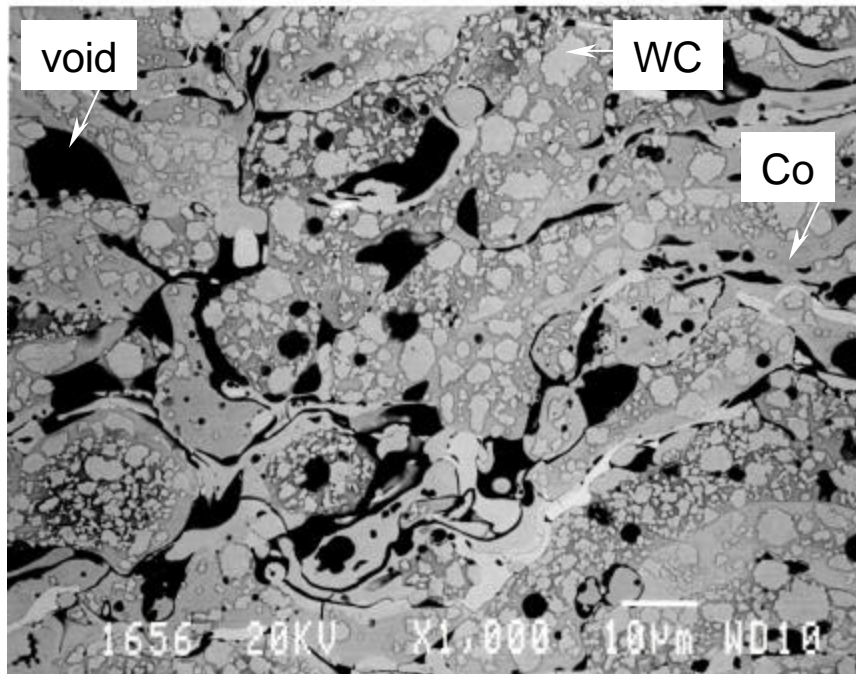


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- Large, heavy agglomerates
- Relatively cool
 - Take a long time to heat up
- Relatively low velocity
 - Accelerate slowly in gas jet

Amdry 983 coating (1)

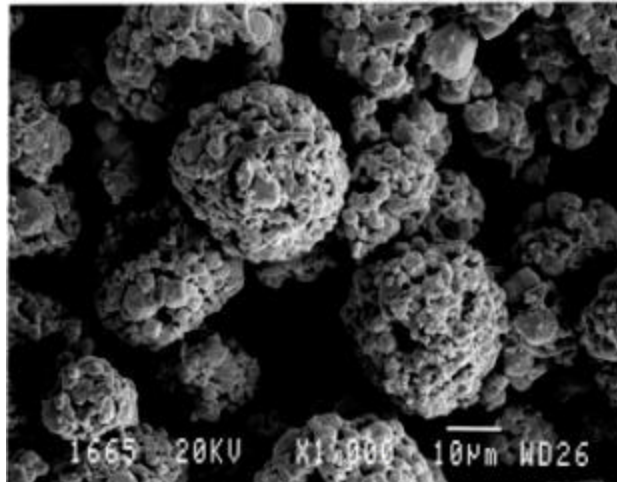


SEM Cross-section - Backscattered

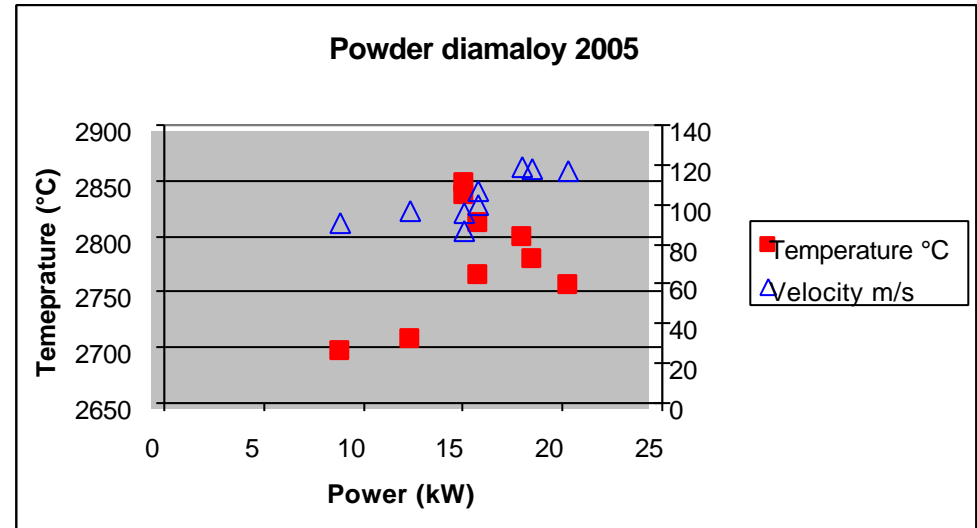
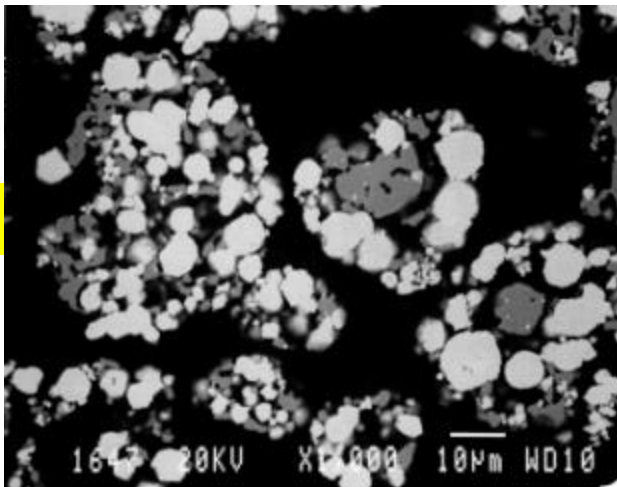
- Large, heavy particles
 - Lowest velocity particles (slowest acceleration)
 - Lowest temperature (highest thermal mass)
 - Carbides well-defined (not dissolved) because of low T
 - Porous because of low V

Spray analysis - Diamalloy 2005 powder

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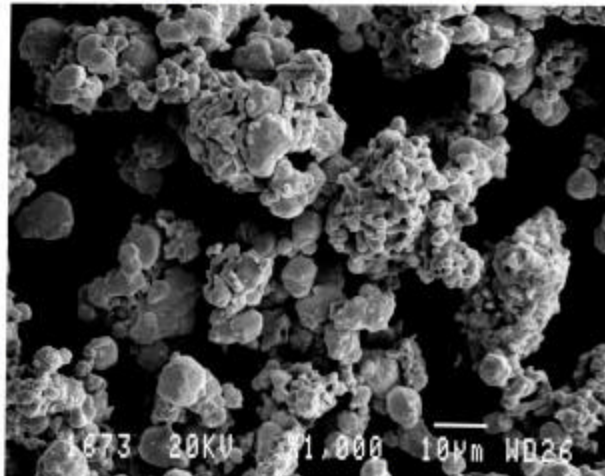
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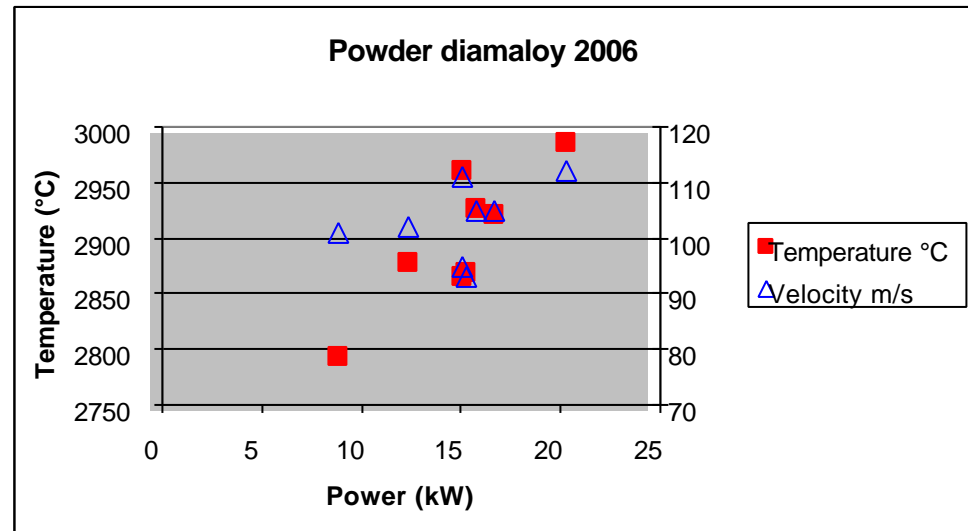
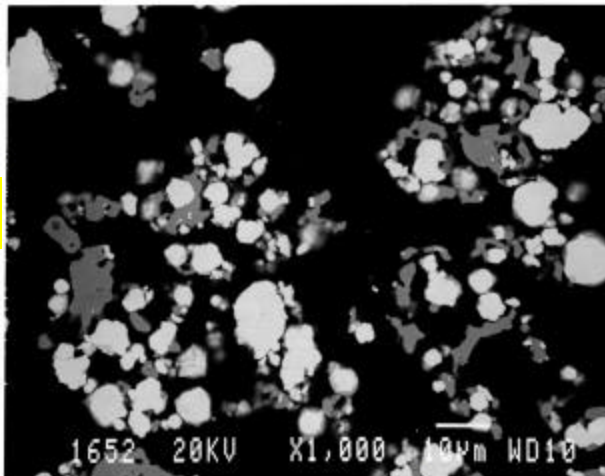
- Lower density particles
- Higher velocity
 - Rapid acceleration to full speed at nozzle exit
- Heat up more quickly
 - Reach higher temperatures

Spray analysis example - Diamalloy 2006 powder

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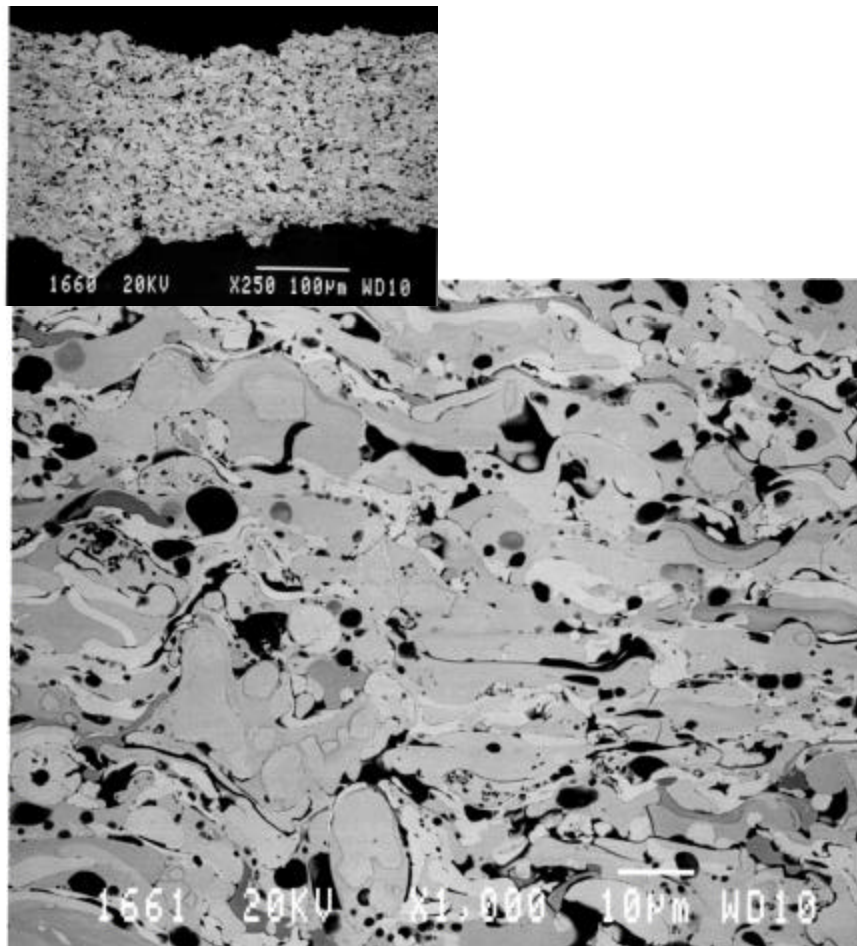


BEI



- Smallest particles
- Highest temperatures and velocities

Diamalloy 2006 coating (3)



- Smallest particles
 - highest velocity and temperature
- Relatively low porosity
- Almost complete carbide dissolution
 - Far too high a particle temperature (Co partially evaporates away)

Summary of particle temperature and velocity data

- Particle T and V vs spray conditions
 - Diamalloy V ~ 120ms^{-1} for most spray conditions
 - Amdry powder much heavier and slower
 - Smaller particles and higher velocities appear to give lower porosity, as expected
 - Can easily overheat and degrade WC, as expected, so need to control deposition conditions, stand-off etc.
 - Can define allowable ranges of temperature and velocity for different particle sizes and materials

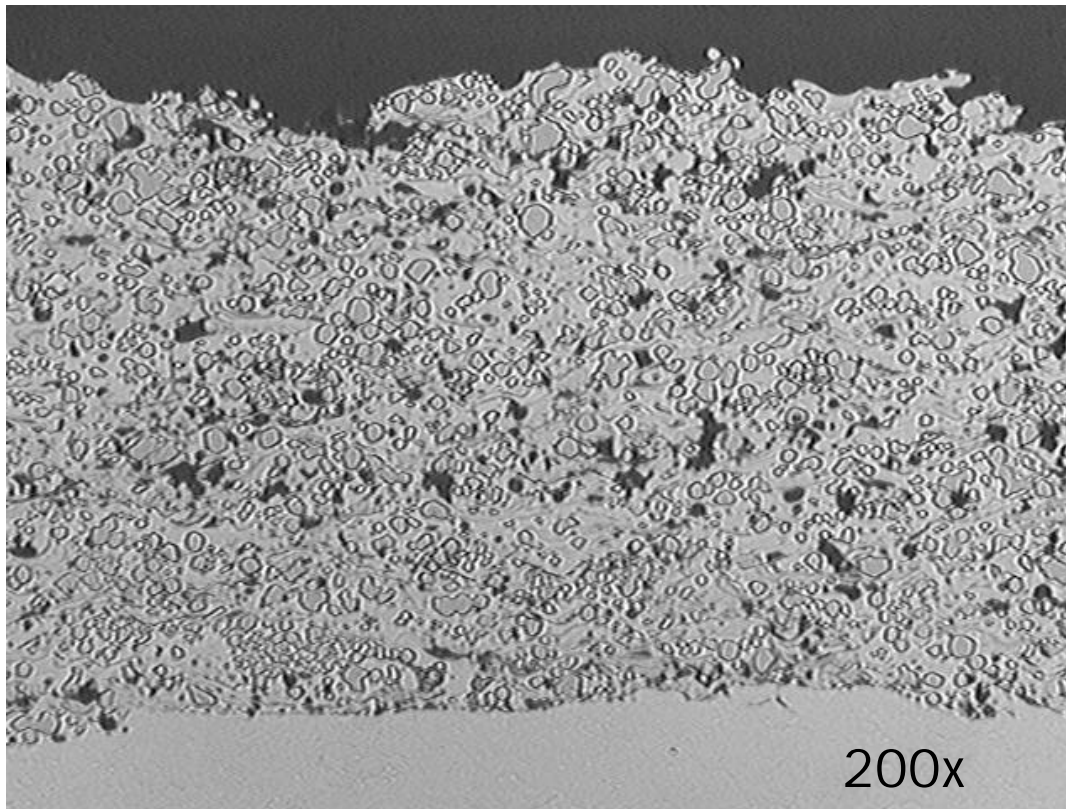
Conclusions from initial NRC study

- Behavior pretty much as expected
- Ideal powder different for different sized guns and different power levels
- Very easy to overheat powder with high-power gun
 - Especially with smaller powders
 - Result is WC dissolution
 - Need to aim for lower power, but with highest possible velocity to minimize porosity

Sulzer Metco initial study

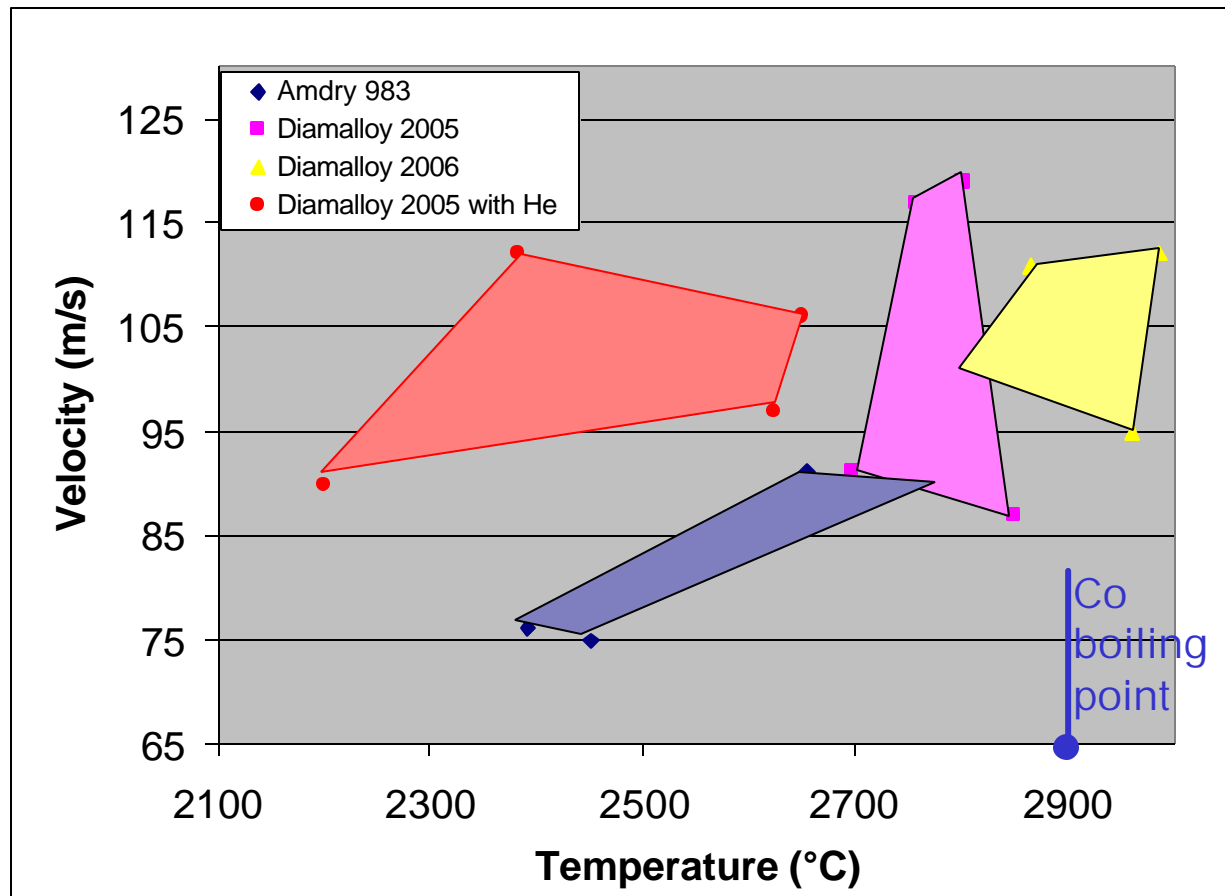
Run Number	Gun Type	Powder	Primary (Ar)	Secondary (He)	Standoff (inch)	Power (kW)
91011-1	F-100	2005NS	45 SLPM	10 SLPM	1.25"	10.9
91011-2	F-100	2005NS	45 SLPM	20 SLPM	1.25"	11.2
91011-3	F-100	2005NS	45 SLPM	40 SLPM	1.25"	12.3
91011-4	F-100	2005NS	45 SLPM	80 SLPM	1.25"	14.0
91011-5	F-100	2005NS	45 SLPM	160 SLPM	1.25"	15.6
91011-6	F-100	2005NS	45 SLPM	200 SLPM	1.25"	16.3
91013-2	F-210	2005NS	45 SLPM	10 SLPM	1.5"	9.5
91013-3	F-210	2005NS	45 SLPM	20 SLPM	1.5"	10.5
91013-4	F-210	2005NS	45 SLPM	40 SLPM	1.5"	11.7
91013-5	F-210	2005NS	45 SLPM	80 SLPM	1.5"	12.6
91013-6	F-210	2005NS	45 SLPM	160 SLPM	1.5"	14.4

Sulzer Metco initial study



- Run 91011-1
 - low He, low kW
- Porosity 9%
- Hardness 764 HV₃₀₀
- Well-defined microstructure
- Optimization proceeding for both guns
 - coordinating with NRC

Diamalloy 2005 + He at NRC Based on Sulzer Metco conditions



- He secondary gas allows
 - Lower T
 - Higher V
 - Good microstructure
- T and V to be measured closer to gun
- Optimization to be done on both guns
 - transfer to Sulzer Metco

Praxair Tribaloy 400 initial testing

- 2700 gun
- 2" stand-off, 10-42 gpm
 - approx. 0.001"/min on 12" long x 3" ID tube
- Coated in 3" ID tube
- Three powders
 - -325 mesh (44 μ m) baseline and -400 mesh (37 μ m) smallest available
 - -500 mesh (30 μ m)
 - ❑ Produced for project
 - Porosity greatly improves as go from standard 44 μ m to 30 μ m powder
 - ❑ fine powder harder to feed
- To be done next
 - Measure properties of coatings so far
 - Develop parameters and coat ID with 30 μ m powder
 - Improve powder feed for fine powder

Conclusions so far

- Coating deposition behaves pretty much as expected
 - Have enough power to easily overheat powder with F100 gun
 - However, addition of He reduces T while maintaining V
 - Can make reasonable quality WC-17Co coatings
 - Beginning to make reasonable quality T400 coatings
 - As expected, powder feed more difficult with small powders
 - Can coat at high rate
 - We are now in position to optimize and make samples for process development
- NRC now has sample holder and Praxair, Sulzer Metco guns needed for output characterization and optimization